SEMI-ANNUAL PROGRESS REPORT

NATIONAL AERONAUTICS AND SPACE

ADMINISTRATION RESEARCH GRANT

HYDRODYNAMICS OF TIRE HYDROPLANING

Research Project B-608

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INTRODUCTION

The objective of this study, as set forth in the proposal, is to determine theoretically the incipient lift-off conditions for hydroplaning and to compare the results with existing experimental data. A solution has been effected and numerical results obtained for the mathematical model formulated in the proposal. The model is for a plane jet of inviscid fluid impinging on a curved boundary (tire) which is in contact with a plane, solid surface (pavement). This model was chosen to simulate partial hydroplaning conditions. The shape of the curved surface has been chosen to be arbitrary--in fact the nature of the technique chosen to effect the solution dictates that the shape of the curved boundary be arbitrary. Numerical results have been obtained for various realistic shapes of the curved surface (tire).

RESEARCH COMPLETED

The theory for partial hydroplaning for a curved boundary of arbitrary shape (not specified *a priori*) has been formulated and checked for several shapes. The shape of the curved surface is determined upon assuming arbitrary functions describing the velocity distribution on the surface itself. The functions assumed in effecting the solution give sensible shapes for the curved surface. The technique for solving the problem is as follows. A physical plane (z-plane) is first visualized and drawn as shown in Figure 1a. The shape of curved surface BC is not known *a priori*. The streamline-potential plane (w-plane) is deduced from the z-plane as shown in Figure 1b. It can be proved that Laplace's equation is satisfied for δ , the angular coordinate of the velocity vector, and $\ln V/U$, in the w-plane. One then has a boundary-value problem for or $\ln V/U$ in the w-plane. Since the w-plane is rectilinear rather than curved it is easier to solve the boundary-value problem in that plane. The boundary conditions are thus specified on straight rather than curved lines. However, because of mixed boundary conditions on δ along a given line in the w-plane an auxiliary plane, the w'-plane, is used. The boundary-value problem for δ in the w'-plane is indicated in Figure 1c. The technique of Fourier Series is used to solve for δ in the w'-plane.

If the specified boundary angle on BC

$$\delta = \pi(1-m) - \frac{\pi}{K} \sin \frac{\pi}{2} \frac{\Phi'}{\Phi_c}$$

in which m and k are constants, a sensible curved surface results. If $m = 0.15$ and $k = 4$ the curved surface shown in Figure 2 is obtained. The lift coefficient

$$C_L = \frac{L}{\rho U^2 b\ell/2}$$

in which L is the lift force, ρ the fluid density, b the span, and ℓ the wetted length of curved surface, is shown in Figure 3 for various values of m and k.

RESEARCH PLANNED

In comparing the results with experiment one is confronted with the apparent difficulty of accounting for the three-dimensionality of the physical configuration. In order that a sensible comparison can be made between two-dimensional theory and three-dimensional reality and that the effect of the aspect ratio can be ascertained the problem of total hydroplaning of a flat plate in shallow water--for which experimental results are available (NACA TN 3642)--is being formulated. The theory is being formulated such that total hydroplaning of a curved surface may also be included. At the present time a computer program is being written to evaluate the mathematical expressions that occur in the solution.

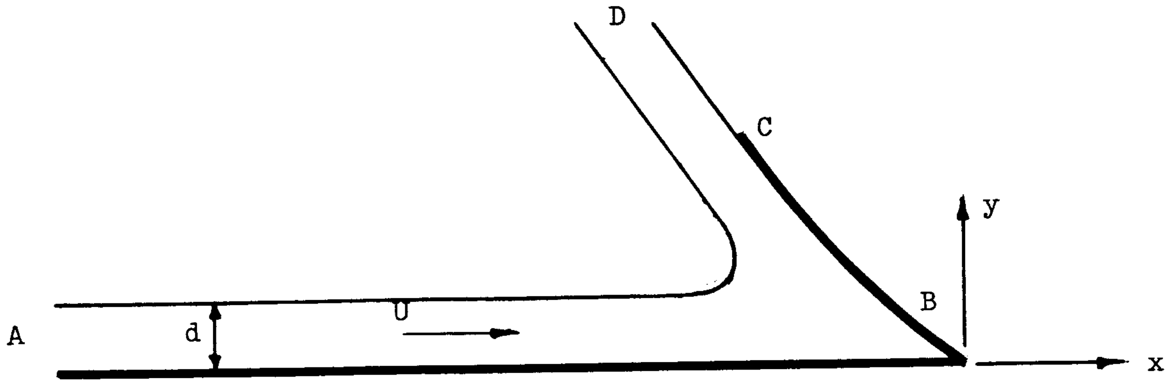

FIGURE 1a. z-plane

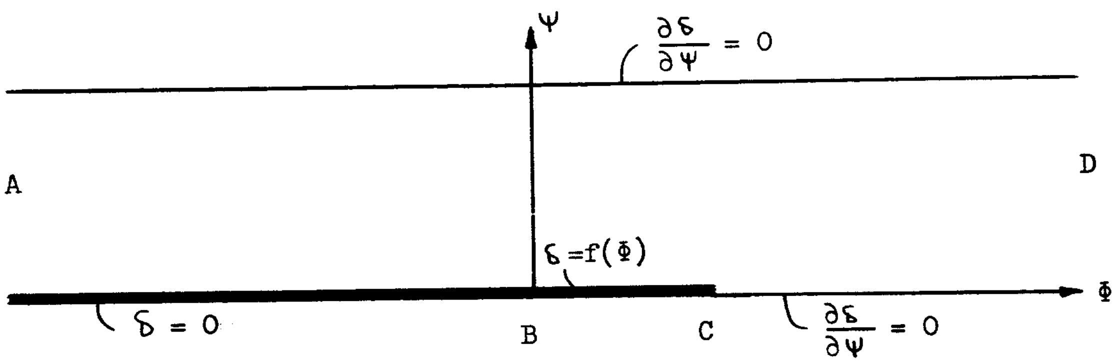

FIGURE 1b. w-plane

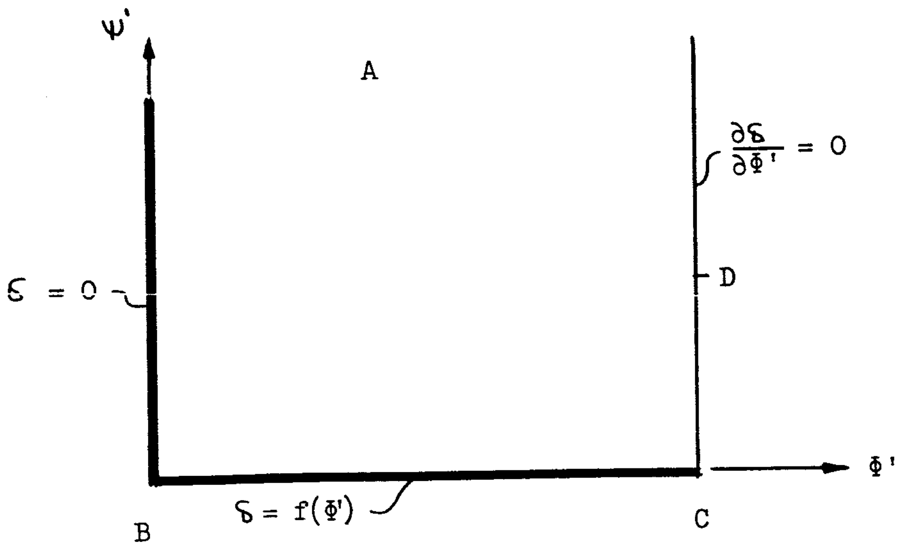

FIGURE 1c. w'-plane

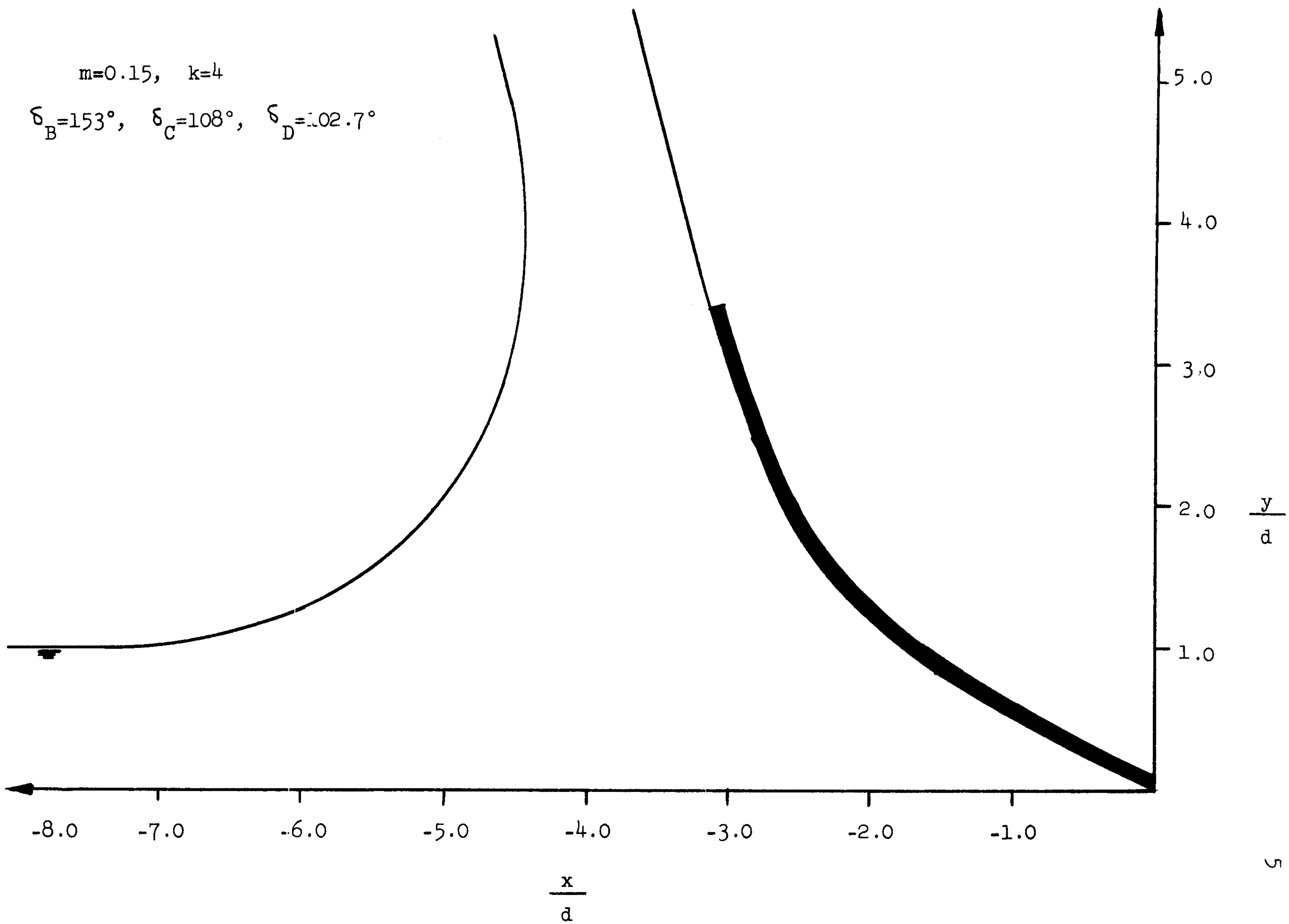
m=0.15, k=4
δ_B=153°, δ_C=108°, δ_D=102.7°
5.0
4.0
3.0
2.0
1.0
$\frac{y}{d}$
-8.0
-7.0
-6.0
-5.0
-4.0
-3.0
-2.0
-1.0
$\frac{x}{d}$

FIGURE 2

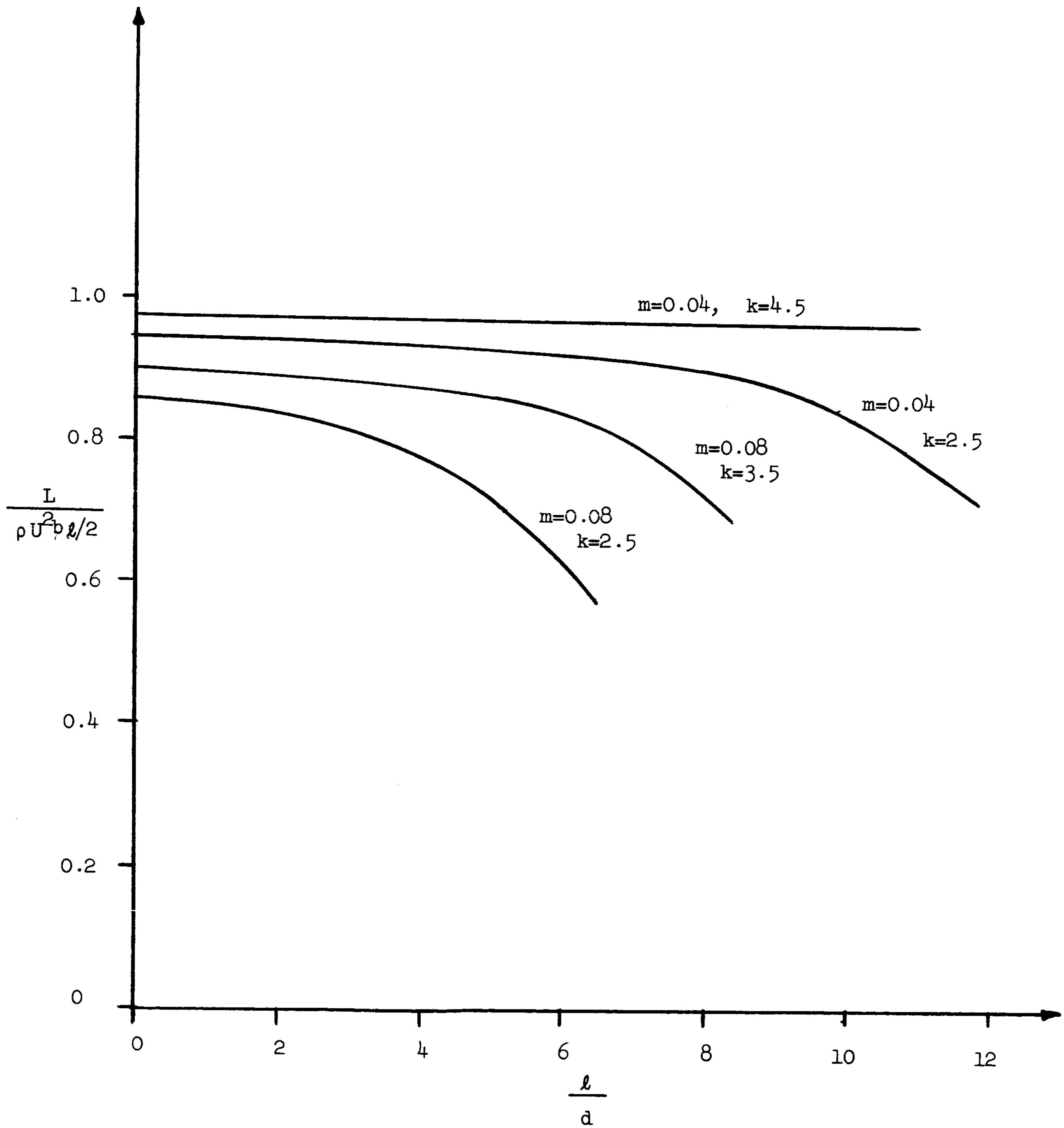
1.0
0.8
0.6
0.4
0.2
0
$\frac{L}{\rho U^2 b \ell/2}$
m=0.04, k=4.5
m=0.04
k=2.5
m=0.08
k=3.5
m=0.08
k=2.5
0
2
4
6
8
10
12
$\frac{\ell}{d}$

FIGURE 3